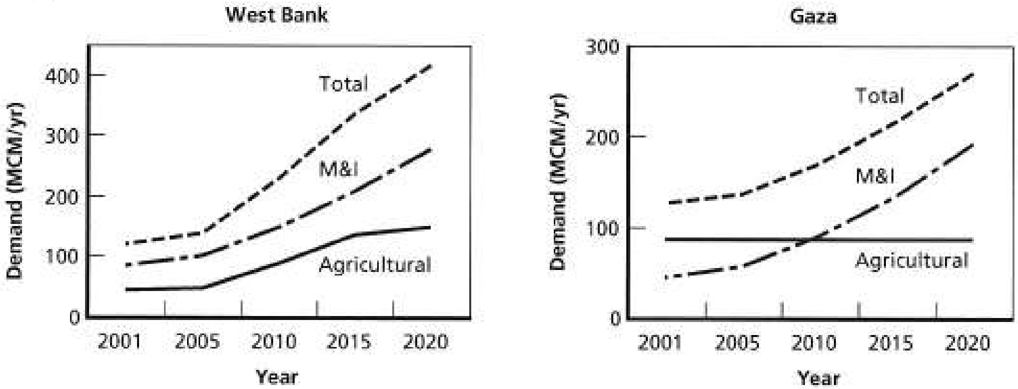
EXHIBIT A.521

(10 of 17)

Figure 6.5
Projected Water Demand for the West Bank and Gaza in the Base Case Scenario



RAND MG146-6.5

demand also increases dramatically: from 126 MCM/yr in 2001 to 217 MCM/yr in 2015 and then to about 274 MCM/yr in 2020. As agricultural demand is specified to remain constant at 84 MCM/yr (2001 levels), demand growth is driven by population growth and the associated municipal and industrial consumption.

Supply

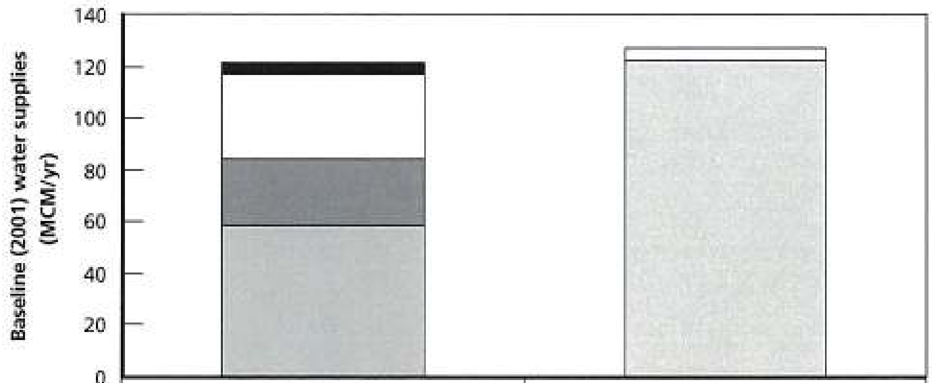
Baseline. For all scenarios, we start with the 2001 baseline supplies shown in Figure 6.6. Groundwater (springs and wells) supplies 70 percent of the West Bank water supply and 96 percent of Gaza water supply. Purchases from Mekorot (the Israeli water company) provide 26 percent of the West Bank supply. Finally, rainfall capture provides about 4 percent of the West Bank water supply.[20]

Sustainable Aquifer Use. The basis for the analysis is that consumption from the aquifers will be sustainable by both the Israelis and Palestinians. To model different water management strategies and estimate project costs, we choose a possible sustainable aquifer-sharing regime as a starting point. The one chosen is not a recommendation, nor should it be considered an optimal plan. Any actual aquifer-sharing scheme will result from future bilateral agreements. The historical, legal, and ethical issues pertaining to the division of groundwater resources are beyond the scope of this book. We assume, however, that the international community will provide financial support for the Palestinians to develop needed water resources and to increase efficiency and for Israel to develop new water sources to replace reductions in aquifer withdrawals. For simplicity and to provide an upper bound on costs, we choose desalination as the source for new Israeli water.[21]

[20] Other estimates suggest that Palestinian water consumption in 2001 was about 20 percent greater than the estimates used here.

[21] Although Israel may also increase its water use efficiency, analysis of Israeli water consumption is beyond the scope of this book.

Figure 6.6
Baseline Water Supplies for the West Bank and Gaza



	West Bank	Gaza
Rainfall	5	0
Mekorot	32	5
Springs	26	0
Wells	59	122

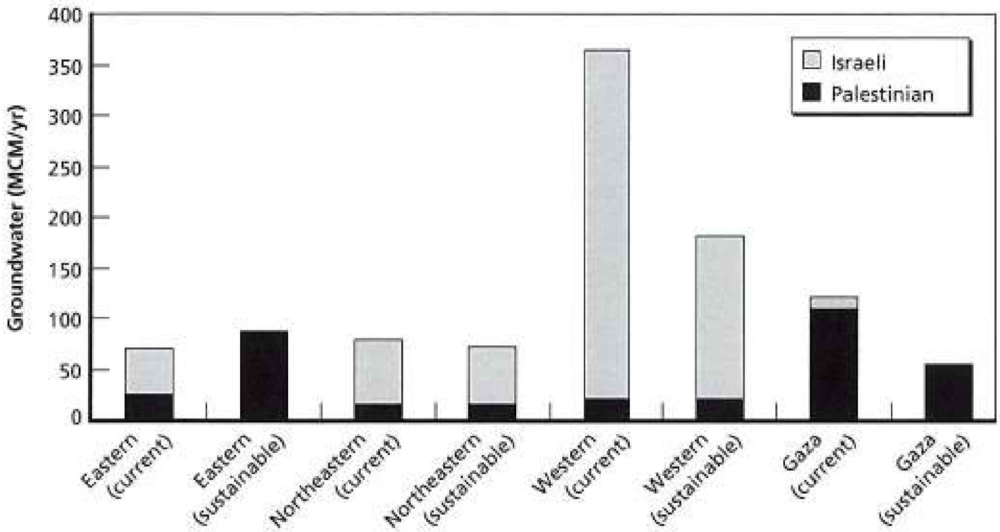
SOURCE: PCBS, 2003.
RAND *MG146-6.6*

In this aquifer-sharing scheme, we assume that Israelis gradually stop drawing from the Eastern Aquifer to bring it to balance over ten years. They reduce their use of the northeast and western basins to bring them into balance by 2010 and 2015, respectively. Finally, we assume that use of the Gaza Aquifer is significantly reduced to bring the aquifer into balance. Figure 6.7 summarizes the sustainable aquifer withdrawal schedules used in the model.

This brings the Eastern, Northeastern, Western, and Gaza Aquifers into balance with sustainable yields by 2005, 2010, 2015, and 2020, respectively. Overdraft will occur prior to these years and will exceed 1,500 MCM for the West Bank Aquifers, and just about reach 500 MCM for the Gaza Aquifer. The implications of this overdraft for water quality are uncertain. Substantial degradation, however, is already apparent in the Gaza Aquifer and to a lesser extent in the West Bank. The Israelis and Palestinians may find it necessary to accelerate this schedule to reduce the harmful effects on the aquifers. This would substantially increase the cost of meeting future water needs. It is important to note that this sharing scheme will work only if historical weather patterns prevail. If drought conditions persist in the region, the sustainable levels will change. The costs of unsustainable use of aquifers can be large. A more detailed analysis should consider the increased water treatment and other mitigation costs required if aquifer quality is degraded.

New Supply. Demand is met by existing and new supply and through efficiency. In the base case, new supply for the West Bank includes new groundwater yielded by

Figure 6.7
Current and Possible Sustainable Aquifer Use by Palestinians and Israelis



RAND MG146-6.7

Israel, rainwater capture, some modest storm water capture, treated wastewater, and desalination (Table 6.7 and Figure 6.8). Although by 2015, efficiency accounts for 19 percent of the total water demand, considerable desalination is still required (112 MCM/yr, or 27 percent of total demand). In the agricultural sector (not shown) 15 percent of supplied demand is met by treated wastewater, 11 percent by capture runoff, and 74 percent by groundwater.

For Gaza, groundwater use decreases by about one-half, and the majority of the new water supply comprises treated wastewater (16 MCM/yr) and desalination (143 MCM/yr). System efficiency improvements also stretch the supply by 38 MCM/yr by 2015. Under the base case, in 2015 desalinated seawater meets 56 percent of the total demand and groundwater meets 22 percent (see Table 6.8 and Figure 6.8).

In the base case, Gaza agricultural water use is specified to remain constant over the modeling period, yet groundwater use must decrease by about one-half. These constraints require a considerable amount of desalinated water (about 68 MCM/yr) to be used for agriculture[22] (see Figure 6.9). Agricultural efficiency measures increase the effective use by about 25 MCM/yr from 2001 to 2020. Finally, treated wastewater offsets some (16 MCM/yr by 2015) of the needed new agricultural water supplies.

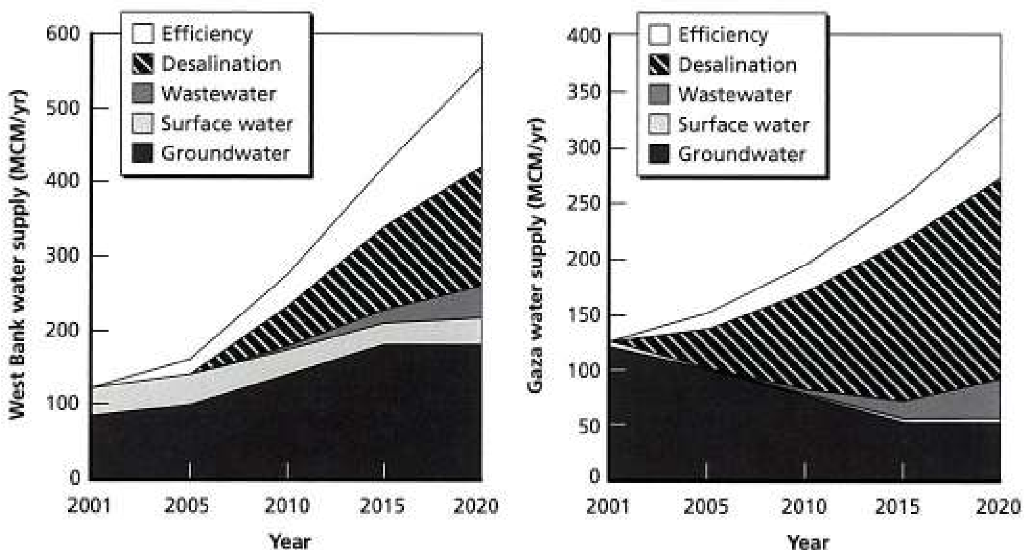
[22] For these scenarios we allocate groundwater to municipal and industrial use first. This results in no available groundwater for agriculture. As we discuss in later scenarios, any non-wastewater supply consumed by the agricultural sector could be used to offset desalinated supplies for the municipal and industrial sectors. So, in effect, any agricultural use of non-wastewater supply increases the desalination requirements for Gaza.

Table 6.7
West Bank Water Supplies for 2001 and 2015 in the Base Case

	2001	2015
	MCM (percentage of total demand)	
Supply	122 (100)	340 (81)
Existing wells	59 (48)	59 (14)
New wells	0 (0)	62 (15)
Springs	26 (21)	60 (14)
Mekorot	32 (26)	0 (0)
Rainwater	5 (4)	13 (3)
Storm water	0 (0)	15 (4)
Reclaimed wastewater	0 (0)	20 (5)
Desalination	0 (0)	112 (27)
Efficiency	0 (0)	80 (19)
Municipal and industrial	0 (0)	42 (10)
Graywater reuse	0 (0)	0 (0)
Agriculture	0 (0)	38 (9)
Total demand	122 (100)	420 (100)

NOTES: Total demand is what would be needed without any efficiency measures in place. Supply plus efficiency equals total demand.

Figure 6.8
West Bank and Gaza Projected Water Supplies in the Base Case, from 2001 to 2020



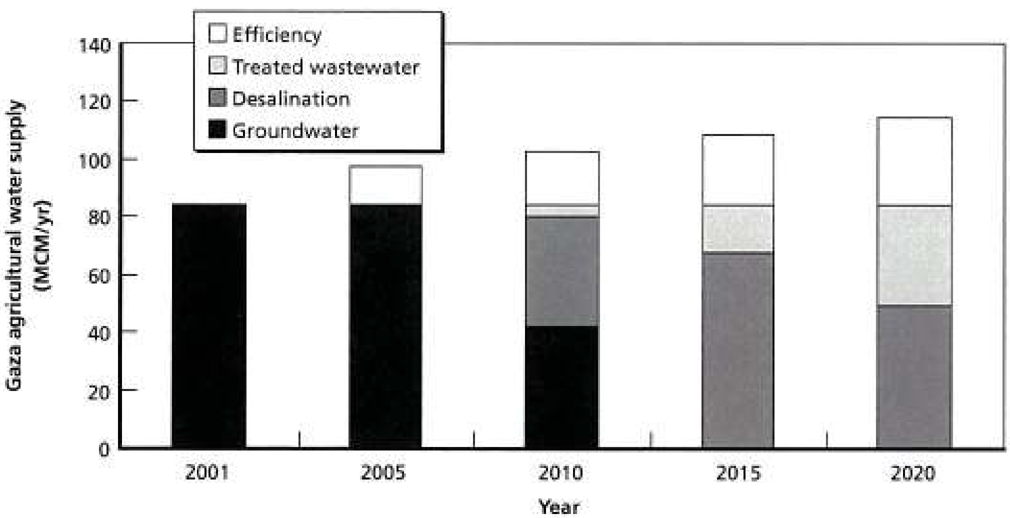
NOTES: Efficiency includes system, domestic, and agriculture efficiency and graywater reuse. Surface water includes rainwater, storm water, and deliveries from Mekorot.
RAND MG146-6.8

Table 6.8
Gaza Water Supplies in the Base Case for 2001 and 2015

	2001	2015
	MCM (percentage of total demand)	
Supply	127 (100)	217 (85)
Groundwater	122 (96)	55 (22)
Mekorot	5 (4)	0 (0)
Rainwater	0 (0)	3 (1)
Reclaimed wastewater	0 (0)	16 (6)
Desalination	0 (0)	143 (56)
Efficiency	0 (0)	38 (15)
Municipal and industrial	0 (0)	14 (5)
Graywater reuse	0 (0)	0 (0)
Agriculture	0 (0)	25 (10)
Total demand	127 (100)	256 (100)

NOTES: Total demand is what would be demanded without any efficiency measures in place. Supply plus efficiency equals total demand.

Figure 6.9
Gaza Agricultural Water Sources in the Base Case



NOTES: The efficiency portion of supply is water that is saved through increased efficiency and improved agricultural techniques. Actual water supplied to agriculture is only the sum of groundwater and treated wastewater.
RAND MG146-6.9

Costs

The total cost for the ten-year period from 2005 through 2014 for upgrading and meeting water needs in the West Bank and Gaza is about $4.9 billion (see Table 6.9). This includes $1.1 billion in aid to Israel for desalination to compensate Israel for reducing its withdrawals from the aquifers. Efficiency costs are modest ($260 million, excluding administration). Wastewater treatment and desalination (along with their share of the administration costs) are the largest single-cost items. Note the high costs of desalination ($900 million) and wastewater treatment ($1.61 billion) for the West Bank and Gaza.

Table 6.9
Base Case Scenario Project Cost from 2005 Through 2014 (in millions of 2003 US$)

	West Bank	Gaza	Palestine	Israel	Total
Domestic efficiency and graywater	76	55	131	0	131
Agricultural efficiency	55	74	129	0	129
Rainwater harvesting	50	39	89	0	89
Wastewater treatment and reuse	581	516	1,097	0	1,097
New wells and storm water	288	0	288	0	288
Desalination	395	503	898	877	1,775
Infrastructure	429	8	437	0	437
Administration	468	299	767	219	986
Total	$2,342	$1,494	$3,836	$1,096	$4,932

Increased Efficiency Scenario

The base case requires significant investment in desalination in order to meet demand. The need for desalination can be mitigated through more aggressive efficiency measures and adoption of alternative new supplies such as rainwater harvesting and reuse of treated wastewater. Efficiency measures are smaller scale, more modular, and can be adopted more rapidly than desalination. The increased efficiency scenario explores one possible policy approach. The scenario is aggressive and it would be difficult to meet the efficiency goals. However, experience in other sectors, such as energy, suggests that this may be feasible. Table 6.10 shows the differences between the base case and the increased efficiency scenario (all other parameters are the same—see Table 6.6).

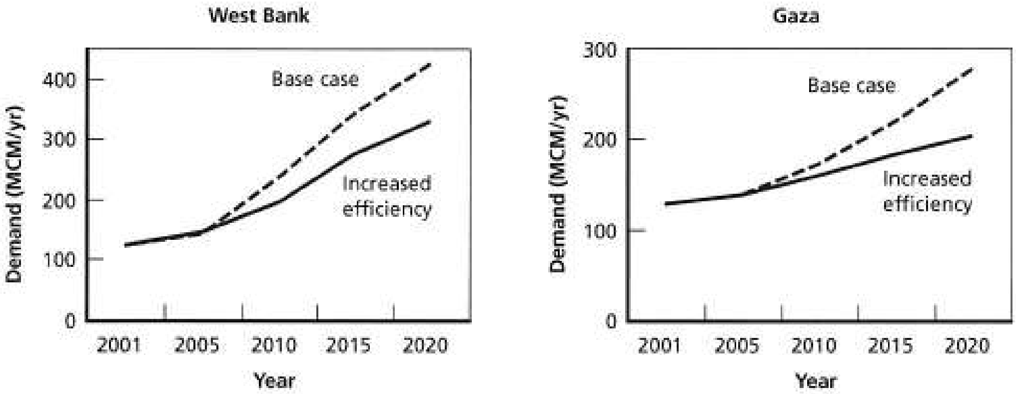
Demand Projections. Increasing efficiency measures are projected to reduce future water demand substantially. Figure 6.10 shows the projected demand for the West Bank and Gaza in the base case and in the increased efficiency scenario. The efficiency measures in the increased efficiency scenario reduce 2015 demand by 20 percent in the West Bank and 17 percent in Gaza.

Supply. As shown in Table 6.11 and Figure 6.11, efficiency meets about a third of the West Bank water demand, and no desalination (or transboundary pipeline) is required. Reclaimed wastewater supplies 51 MCM/yr (12 percent of the total demand) and rainwater capture supplies 25 MCM/yr (6 percent of the total demand) in 2015.

Table 6.10
Select Policy Options for the Base Case and the Increased Efficiency Scenario (in percentage)

Policy	Base Case	Increased Efficiency Scenario
Households adopting domestic efficiency by 2015	12	40
Households adopting graywater systems by 2015	0	40
Households utilizing cisterns	35	70 (WB) / 35 (Gaza)
Municipal and industrial and agricultural system losses in 2015	29	22
Wastewater reuse for agriculture	20	65

Figure 6.10
Total Water Demand in the Base Case and in the Increased Efficiency Scenario for the West Bank and Gaza



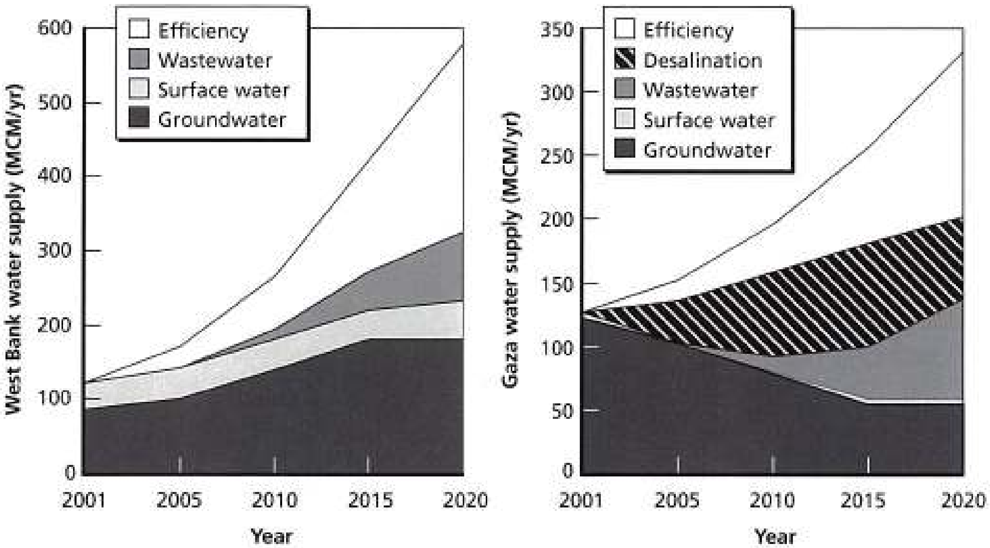
RAND MG146-6.10

Table 6.11
West Bank Water Supplies in the Increased Efficiency Scenario for 2001 and 2015

	2001	2015
	MCM (percentage of total demand)	
Supply	122 (100)	272 (65)
Existing wells	59 (48)	59 (14)
New wells	0 (0)	62 (15)
Springs	26 (21)	60 (14)
Mekorot	32 (26)	0 (0)
Rainwater	5 (4)	25 (6)
Storm water	0 (0)	15 (4)
Reclaimed wastewater	0 (0)	51 (12)
Desalination	0 (0)	0 (0)
Efficiency	0 (0)	148 (35)
Municipal and industrial	0 (0)	59 (14)
Graywater reuse	0 (0)	40 (10)
Agriculture	0 (0)	50 (12)
Total demand	122 (100)	420 (100)

NOTES: Total demand is what would be demanded without any efficiency measures in place. Supply plus efficiency equals total demand.

Figure 6.11
West Bank and Gaza Projected Water Supplies in the Increased Efficiency Scenario, from 2001 to 2020



NOTES: Efficiency includes system, domestic, and agriculture efficiency and graywater reuse. Surface water includes rainwater, storm water, and deliveries from Mekorot.
RAND MG146-6.11

In Gaza, increased efficiency, domestic graywater reuse, and increased wastewater treatment used for irrigation reduce the need for desalination (from 143 MCM/yr to 82 MCM/yr) (see Table 6.12 and Figure 6.11). By 2015, efficiency in municipal and industrial and agriculture plus graywater reuse meets 29 percent of the total demand. Of the supplied water, 32 percent is desalinated seawater, 22 percent is groundwater, 16 percent is reclaimed wastewater, and 1 percent is from rainwater.

Figure 6.12 shows the projected water supply in 2015 for the West Bank and Gaza in the base case and in the increased efficiency scenario. In the increased efficiency scenario, efficiency and increased used of wastewater replaces much of the desalination required in the base case.

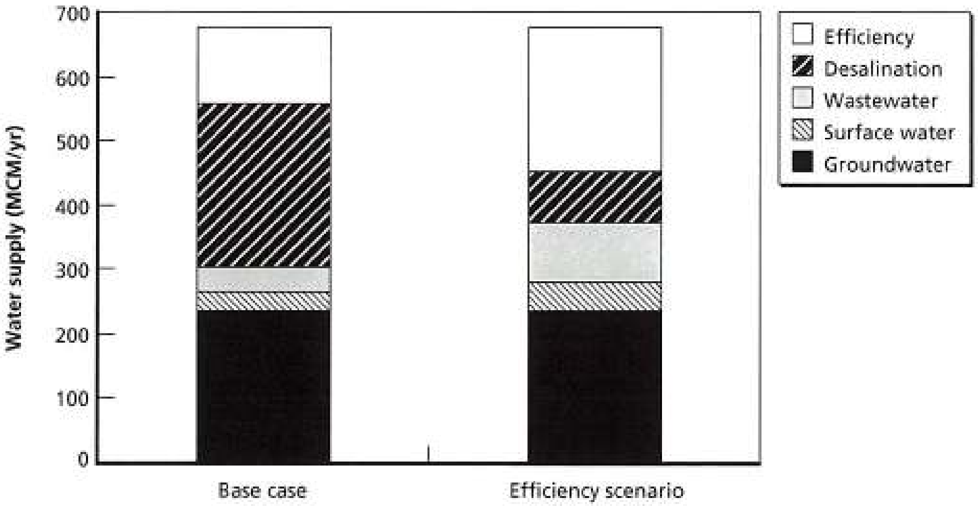
Costs. Pursuing an increased efficiency strategy could reduce the cost of meeting water demand in the West Bank and Gaza from about $4.9 billion to $3.8 billion for the 2005–2014 time period (see Table 6.13). For the West Bank, domestic efficiency and graywater system costs increase from $76 million to $137 million, and rainwater harvesting increases from $50 million to $125 million. This reduction of demand and supply that does not need desalination eliminates the desalination costs ($395 million plus administration) and the associated pipeline infrastructure costs (about $420 million). Another important cost difference is in wastewater treatment and reuse. In the base case, these costs are nearly $600 million for the West Bank. In the increased efficiency scenario, these costs are reduced to just over $500 million, yet the amount

Table 6.12
Water Supplies for Gaza in the Increased Efficiency Scenario for 2001 and 2015

	2001	2015
	MCM (percentage of total demand)	
Supply	127 (100)	181 (71)
Groundwater	122 (96)	55 (22)
Mekorot	5 (4)	0 (0)
Rainwater	0 (0)	3 (1)
Reclaimed wastewater	0 (0)	41 (16)
Desalination	0 (0)	82 (32)
Efficiency	0 (0)	75 (29)
Municipal and industrial	0 (0)	26 (10)
Graywater reuse	0 (0)	24 (9)
Agriculture	0 (0)	25 (10)
Total demand	127 (100)	256 (100)

NOTES: Total demand is what would be demanded without any efficiency measures in place. Supply plus efficiency equals total demand.

Figure 6.12
Total Palestinian Water Supply for 2015 in the Base Case and in the Increased Efficiency Scenario



RAND MG146-6.12

of treated wastewater available for irrigation increases by over 50 MCM/yr. This illustrates the dual saving power of efficiency—savings result from both reduced water demand and reduced wastewater treatment.

Table 6.13
Increased Efficiency Scenario Project Cost from 2005 Through 2014 (in millions of 2003 US$)

	West Bank	Gaza	Palestine	Israel	Total
Domestic efficiency and graywater	137	92	229	0	229
Agricultural efficiency	76	96	172	0	172
Rainwater harvesting	125	39	164	0	164
Wastewater treatment and reuse	518	463	981	0	981
New wells and storm water	288	0	288	0	288
Desalination	0	322	322	877	1,999
Infrastructure	12	8	20	0	20
Administration	289	255	544	219	763
Total	$1,445	$1,275	$2,720	$1,096	$3,816

In Gaza, efficiency measures result in significant savings in desalination costs ($503 million to $322 million). Despite this decrease in cost, more than half of this desalination still goes toward irrigation (not shown in Table 6.13). In addition, groundwater used for irrigation could be reallocated to the municipal regions, thus further reducing the need for desalination as a supply. Our increased efficiency–reduced Gaza agriculture scenario (described below) explores this possibility.

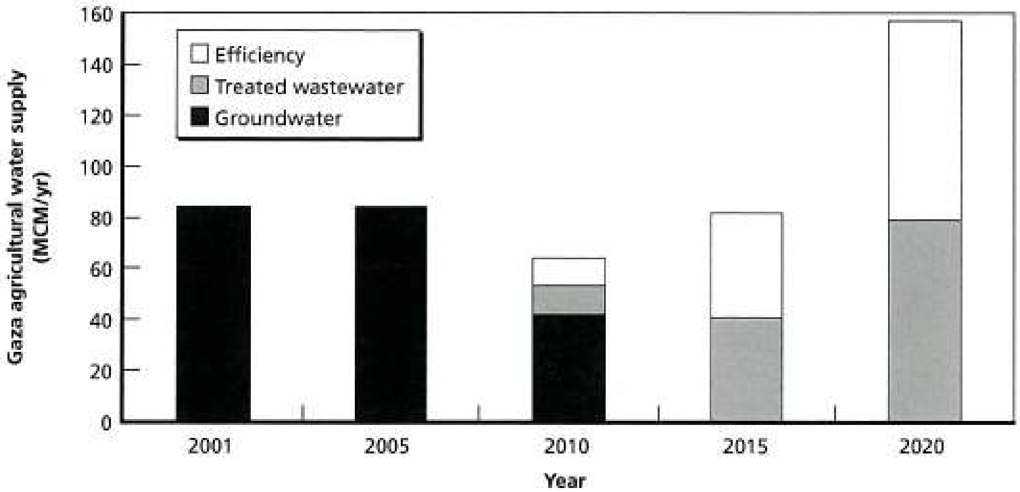
Increased Efficiency–Reduced Gaza Agriculture Scenario

As another policy option, the Palestinian Water Authority might choose to minimize the amount of desalinated water required in Gaza by reallocating all groundwater to municipal and industrial uses. This policy, of course, would have substantial socioeconomic implications in the agricultural sector. It should be viewed only as an extreme policy option and not necessarily the most desirable one. In this scenario, water for irrigation would therefore be supplied only through recycled municipal and industrial wastewater. For this scenario, we use the increased efficiency scenario and modify it for Gaza by eliminating groundwater use for irrigation by 2015. However, because of greater levels of wastewater treatment by 2020, water supplies for irrigation approach the 2001 level (Figure 6.13). Furthermore, by 2020 the effective use is even greater than in 2001 as a result of increased efficiency of water delivery and application in the agricultural sector ("efficiency" in the figure).

A more realistic option, however, might be to transition more slowly away from irrigating with groundwater in Gaza. This would require a larger initial investment in desalination for domestic use in order to accommodate the urgently required reduction in Gaza Aquifer use.

Table 6.14 and Figure 6.14 show the supplies for all sectors in Gaza in the increased efficiency–reduced Gaza agriculture scenario. In contrast to earlier scenarios, only 39 MCM/yr of desalinated water is needed (versus 143 MCM/yr for the base case and 82 MCM/yr for the increased efficiency scenario). Note the large amount of

Figure 6.13
Gaza Agricultural Water Sources in the Increased Efficiency–Reduced Gaza Agriculture Scenario



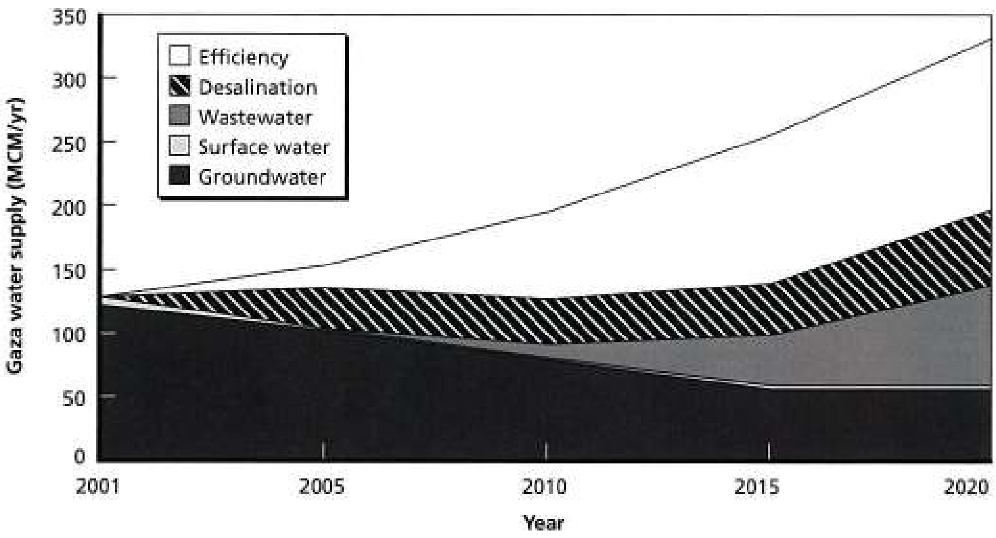
NOTES: The efficiency portion of supply is water that is saved through increased efficiency and improved agricultural techniques. Actual water supplied to agriculture is only the sum of groundwater and treated wastewater.
RAND MG146-6.13

Table 6.14
Gaza Water Supplies in the Increased Efficiency–Reduced Gaza Agriculture Scenario, for 2001 and 2015

	2001	2015
	MCM (percentage of total demand)	
Supply	127 (100)	138 (54)
Wells and springs	122 (96)	55 (22)
Mekorot	5 (4)	0 (0)
Rainwater	0 (0)	3 (1)
Treated wastewater	0 (0)	41 (16)
Desalination	0 (0)	39 (15)
Efficiency	0 (0)	117 (46)
Municipal and industrial	0 (0)	26 (10)
Graywater reuse	0 (0)	24 (9)
Agriculture	0 (0)	68 (26)
Total demand	127 (100)	256 (100)

NOTES: Total demand is what would be demanded without any efficiency measures in place. Supply plus efficiency equals total demand.

Figure 6.14
Gaza Projected Water Supplies in the Increased Efficiency–Reduced Gaza Agriculture Scenario, from 2001 to 2020



NOTES: Efficiency includes system, domestic, and agricultural efficiency and graywater reuse. Surface water includes rainwater, storm water, and deliveries from Israel.
RAND *MG146-6.14*

water supply that comes from treated wastewater. The cost savings from reallocating all groundwater away from irrigation and toward municipal and industrial uses is about $240 million (not shown in the figure or the table).

There are several important lessons to be learned from this extreme scenario. First, even if groundwater were to be used only for domestic consumption in Gaza, substantial desalination would be required. This implies that any irrigation using Gaza groundwater should be valued at least as high as the cost of providing that water through desalination or at the cost of forgoing domestic consumption. Second, efficiency and wastewater reuse must be aggressively pursued in Gaza. The dual goal of providing for the projected future population in Gaza and supporting an agricultural industry cannot be achieved without bold efficiency and wastewater reuse policies. Finally, the tradeoffs between domestic and agricultural consumption necessitates creating water and agricultural development policies concurrently, using an integrated framework.

Robust Policies

A robust policy is one that is relatively insensitive to major assumptions and unknown parameters. As discussed above, future water demand, available supplies, and costs are all subject to large uncertainties. It is critical, therefore, to evaluate candidate policy strategies against ranges of the uncertain parameters.

There are numerous uncertain parameters that affect the cost estimates. Two important parameters are population growth rates and energy prices. Much of the future water demand is driven by population growth, and the potential return of refugees introduces significant uncertainty into population projections. Energy prices affect the cost of different policies primarily through the high energy requirements of distribution of fresh water, the treatment of consumed water, and desalination.

Table 6.15 summarizes the costs (from 2005 to 2014) for the base case and increased efficiency–reduced Gaza agriculture scenario under the following conditions: (1) expected energy costs and population growth, (2) high energy costs, (3) high population growth, and (4) high energy costs and high population growth. For the high population growth scenarios, population growth in the West Bank and Gaza is set at 4.3 percent per year and 5.2 percent per year, respectively. This population growth rate increase results in 715,000 more Palestinians in the West Bank and Gaza by 2015. At the high end of energy projections, it is possible that energy costs might increase as much as 3 percent per year[23]—based on uncertainty surrounding costs of the potential natural gas discoveries mentioned above.

Table 6.15
Project Costs from 2005 to 2014 for the Base Case and the Increased Efficiency–Reduced Gaza Agriculture Scenario Under Expected Energy Costs and Population Growth, High Energy Costs, High Population Growth, and High Energy and High Population Growth Conditions (in millions of 2003 US$)

	Base Case				Increased Efficiency–Reduced Gaza Agriculture Scenario			
	Expected Energy Costs & Pop. Growth	High Energy Costs	High Pop. Growth	High Energy Costs & Pop. Growth	Expected Energy Costs & Pop. Growth	High Energy Costs	High Pop. Growth[a]	High Energy Costs & Pop. Growth[a]
WB and Gaza	3,834	4,161	4,209	4,569	2,478	2,529	2,678	2,740
WB	2,340	2,553	2,562	2,795	1,443	1,464	1,507	1,527
Gaza	1,494	1,608	1,647	1,774	1,035	1,065	1,171	1,213
Israel	1,096	1,294	1,096	1,294	1,096	1,294	1,096	1,294
Total	$4,930	$5,455	$5,305	$5,863	$3,574	$3,823	$3,774	$4,034

NOTES: Energy costs increase 3 percent per year instead of 1 percent per year under the high-energy-costs conditions. Under the high-population-growth conditions, the population increases yearly by 4.3 percent instead of 3.3 percent in the West Bank and by 5.2 percent instead of 4.2 percent in Gaza.
[a] For the two high-population-growth with increased efficiency cases, graywater system use is increased in the West Bank from 40 percent to 60 percent to accommodate the population growth.

[23] Energy cost increases of 3 percent matches the "high oil price" scenario of the Energy Information Administration, *International Energy Outlook 2003* (EIA, 2003a).

Figure 6.15 shows the phasing of costs from 2005 to 2019 for the base case and increased efficiency–reduced Gaza agriculture scenario. The costs increase substantially over time, reflecting the phasing of desalination for both Gaza and Israel. Note that costs under the base case continue to rise rapidly past 2014, whereas the costs in this efficiency scenario begin to level off.

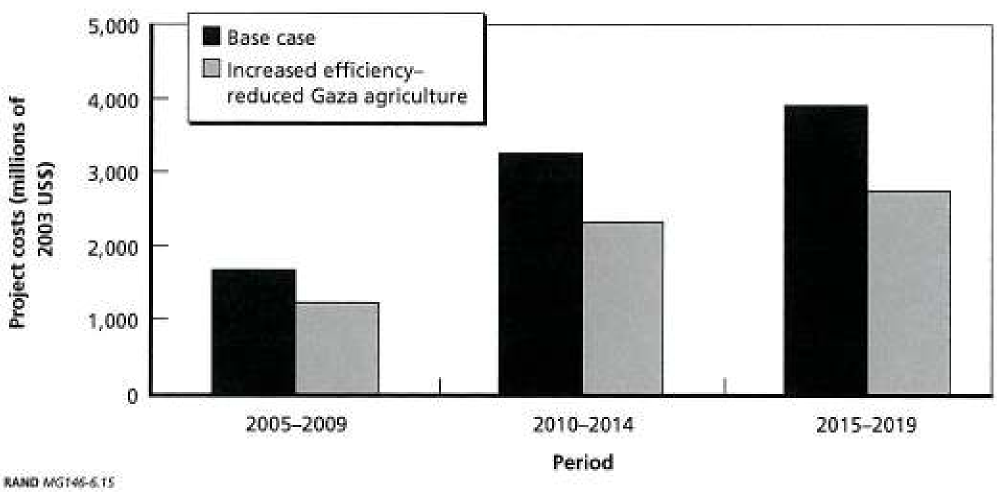
If energy prices are higher than expected, costs might increase about $525 million. In contrast, costs only rise about $250 million under the high efficiency–reduced Gaza agriculture case. This illustrates an important advantage of water efficiency and water reuse—they are less sensitive to volatility in energy price.

In the increased population growth cases, costs increase by $375 million in the base case as opposed to $200 million in the high efficiency–reduced Gaza agriculture scenario. Price rises less quickly under both because each additional person requires less water when efficiency measures are employed and because at these levels increased efficiency can provide effective water more inexpensively than desalination.

Finally, under the worst-case scenario of higher energy prices and greater population growth rates, the project cost could reach about $5.86 billion in the base case but only $4.03 billion in the high efficiency–reduced Gaza agriculture scenario. This potential savings would more than pay for the desalination needed to make up for reductions in Israeli withdrawals from the aquifers.

Figure 6.15 shows the cumulative project costs by period for the base case and high efficiency–reduced Gaza agriculture scenario. For both cases, more than one-half the total costs are realized by 2011, and the costs increase modestly after 2015.

Figure 6.15
Project Cost Phasing for the Base Case and the Increased Efficiency–Reduced Gaza Agriculture Scenario



These results suggest that investing in efficiency can be more robust against population growth and energy price uncertainties. These results reflect differences between efficiency/conservation measures and new water source measures like desalination. Depending less on desalination can hedge against price and demand uncertainty.

Finally, the results indicate that a prudent course of action may be to pursue policies that emphasize an increasing amount of efficiency and distributed supply-enhancing options (e.g., rainwater harvesting and wastewater reuse) in combination with desalination (in Gaza). For the West Bank, this strategy may result in delaying the need for desalination indefinitely (as is the case for the increased efficiency scenarios).

Conclusions

Water issues are only some of the many issues that a possible new Palestinian state will have to face, but they are among the most critical. As we have discussed in this chapter, some water issues urgently need attention. Water supplies do not currently meet the growing population's domestic needs, nor are they sufficient for irrigation expansion. Aquifers are already being overused, and they are becoming increasingly contaminated, directly threatening both health and productivity. Finally, the water and wastewater infrastructure is in disrepair, leading to the waste and contamination of scarce supplies. Substantial investment in this infrastructure will be required to support a viable Palestinian state. Efforts to improve the situation are needed now.

Our analysis reveals several major lessons. First, creating a reliable water and wastewater system for a future Palestinian state will be possible only through the use of a variety of policies, including demand management, appropriate agricultural development, infrastructure improvements, enhanced efficiency measures, innovative new supply development (e.g., rainwater harvesting and use of treated wastewater), and desalination. The cost of accomplishing these systems, above and beyond current expenditures, will likely exceed $3.5 billion from 2005 through 2014.

Second, utilizing water resources sustainably will require a substantial reduction in the use of groundwater in both the Mountain and Gaza Aquifers. Because these resources underlie both Israeli and the Palestinian territories, cooperation between Israelis and Palestinians will be required. We have used one aquifer-sharing scheme, but there are many other ways to make this allocation. Deviating from the proposed scheme will alter the total price for the project and require different levels of external sources. Although this determination will ultimately be made through negotiations, we encourage both parties to carefully consider the hydrology of the groundwater basins, the projected needs of the regions' inhabitants, and the total project costs when making these determinations. This chapter provides a framework that can be used to evaluate water management schemes.

Next, although desalination is a promising supply option for a Palestinian state, its high relative costs dictate that its use be accompanied by aggressive demand management and efficiency improvements. Our analysis suggests that desalination will be required for Gaza because of its large expected population and scant groundwater resources. As desalination sources are developed for Gaza, a concurrent goal should be to improve the efficiency of water use to the highest achievable levels.

For the West Bank, however, the water supply options are greater. Although some management plans call for desalinated water to be piped from the Mediterranean Sea to the West Bank, our analysis suggests that in the near term it could be less expensive and more prudent to more fully utilize alternative water sources and demand management in lieu of relying on new desalinated water. This strategy would eliminate the need for a transboundary pipeline for desalinated water transport and increase Palestinians' security and control over their water resources.

Through the evaluation of different scenarios with varying future populations and energy prices, we show some positive features of efficiency and demand management. When employed at appropriate levels, these features can provide a hedge against uncertainty in energy prices and demand. Preparing for uncertainty could significantly increase the chances of a successful future Palestinian state.

Appendix 6.A

The appendix contains additional information regarding the costs and yields of various policy scenarios as well as details of the CH2M HILL model used to estimate project costs.

Demand

Municipal and industrial demand is computed by the following equation:

$$MI = \frac{DD}{(1 - Loss) \times (1 - Pub - CI)'}$$

where *MI* is gross municipal and industrial water demand, *DD* is gross domestic demand, *Loss* is physical losses as a percentage of gross municipal and industrial demand, *Pub* is public water demand as a percentage of consumptive municipal and industrial demand, and *CI* is commercial and industrial water demand as a percentage of consumptive municipal and industrial demand.

Baseline municipal and industrial demand is derived from actual supply records from PWA as documented by CH2M HILL (2001). Public and industrial water demand is considered to be a percentage of domestic demand. The model also specifies the commercial and industrial demand as percentages of municipal and industrial demand.

Population, a key determinant of projected demand, is projected to grow in Palestine due to internal growth rate (births exceeding deaths) and net inflow of Palestinians. The PCBS forecasts internal growth rates of around 3.3 percent. The net inflow of Palestinians (returnees) is much more difficult to predict as it depends upon numerous characteristics of the Palestinian state including economic prospects and ability to absorb returnees.

Per-Capita Domestic Consumption. We compute domestic demand as the product of the per-capita consumption rate and the projected population. Estimates of gross per-capita supply rates range from 43 l/d to 50 l/d during 1995–1999.[24] Assuming 40 percent physical losses, public demand equal to 6 percent of municipal and industrial demand (excluding losses) for all time periods (CH2M HILL, 2001), and CI consumption of 7 percent of municipal and industrial demand, the 1999 supply rate is estimated to be 50 l/d per person. CH2M HILL uses the baseline of 55 l/d for 2001. The target per-capita consumption rate is 100 l/d by 2015.

Domestic Efficiency. CH2M HILL estimates that typical water-saving household fixtures such as aerators on faucets, low-water toilets, and low-consumption showerheads will reduce daily consumption by 25 percent for consumers connected to a centralized water system with near constant reliability (the objective of Palestinian

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[24] Source: Table 3 (CH2M HILL, 2001).

water planning). Because most Palestinians do not receive constant and reliable water supplies, current consumption is highly efficient. As a result, CH2M HILL assumes that only 5 to 10 percent of a household's current demand can realistically be reduced via these measures.

While maximum water savings could be significantly higher, we have used 25 percent as a reasonable estimate of water savings. Other sources estimate that efficiency measures could save 15 to 50 percent of a household's consumption (Seckler, 1996). Low-flow toilets alone can reduce water demand by 7 to 15 percent.[25] The use of water displacement devices (such as placing sand-filled containers in the toilet tank) in consort with traditional toilets can save roughly the same amount with nearly no capital investment. Low-flow showerheads can reduce demand by roughly 5 to 15 percent.[26]

We have used CH2M HILL's cost estimates. CH2M HILL estimates that the capital investment necessary to purchase faucet aerators, showerheads, and low-flush toilets range between $168 and $320. These fixtures, assumed to have a lifetime of ten years, will cost roughly $0.15/CM. The yearly operation and maintenance expenditures are estimated to be $30, or $0.11/CM over ten years. These cost estimates are for a household consumption of 787 CM/yr, and estimated savings is 349 CM/yr; a house consuming only 577 CM/yr will have higher costs—$0.20/CM in capital costs and $0.16/CM in operation and maintenance costs.

Domestic Graywater Reuse. Estimates of household water reuse for toilets, domestic irrigation, and washing range from 30 to 80 percent of household consumption (Libhaber, 2003; Faruqui, 2002; Pottinger, 2003). For our analysis, we assume a conservative value of 40 percent. The cost of treating graywater onsite for 20 to 200 people is roughly $50 per capita plus $20–$35 for annual capital and operating expenditures (Al-Sa'ed, 2000). Our model, however, assumes the reuse of untreated graywater for irrigation and toilet water. One case study of wastewater reuse in domestic agriculture in Jordan estimated the average capital cost of graywater systems to be $113. Costs of individual systems ranged from $45 to $229, depending on the system's complexity (Faruqui and Al-Jayyousi, 2002). We assume higher capital costs of $300 to cover any required minor plumbing modifications and small filter needs.[27] We assume annual operation and maintenance costs to be 10 percent of this investment.

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[25] Since toilet water accounts for 20 to 30 percent of household water use (personal communication with Naser I. Faruqui, April 1, 2003) and low-flow toilets use 33–50 percent of a standard toilet (National Research Council, 1999), low-flow toilets alone can reduce household water consumption by 7–15 percent. Dry toilets, although not estimated in our model, could increase this conservation to 20–30 percent of a household's daily consumption.

[26] Low-flow showerheads save 7.5 liters per minute. Assuming only two 2.5-minute showers per day for a household of seven would equal an annual water savings of 13,700 liters, or 13.7 CM, of annual household use. This is equal to over 5 percent of the water demand of a household of seven consuming 700 l/d. Similarly, if there were 14 minutes of showering daily, low-flow showerheads would reduce water demand by 15 percent.

[27] Personal communication with Naser I. Faruqui, April 1, 2003.

New Supplies

Rainwater Harvesting. CH2M HILL (2002a) estimates that 70,000 cisterns, with an average volume of 70 CM each, account for about 5 MCM of the Palestinians' current consumption. CH2M HILL estimates the upper limit for annual usable rainwater to be about 12 MCM/yr if the collection area for rainwater harvesting were increased to 20 percent of the built-up area. This estimate assumes that the cisterns in this portion of the built-up area each yields 140 CM/yr. The capital cost associated with this collection is estimated to be $0.70/CM of water (or $17/CM of developed capacity),[28] and the operation and maintenance costs are assumed to be $0.21/CM. CH2M HILL estimates that rainfall harvesting could expand at a rate of 0.2 MCM/yr until 2005 and at a rate of 0.6 MCM/yr thereafter.

Our estimate assumes a much larger portion of households will use rainwater capture, but that the yield of the capture systems will be lower. Instead of basing collection area on agglomerated areas as CH2M HILL's analysis did, we estimate rainfall harvest potential based on the total number of households and the percentage of households utilizing cisterns. Following the estimates of the UNEP (2001) and the National Research Council (1999), we assume that each cistern yields 70 CM/yr on average. We estimate the total rainwater supply as the product of the estimated number of households and this average capacity. For the West Bank and Gaza, the number of households is the forecasted total population divided by 6.5 and 7, respectively. For our high-efficiency scenario, we assume that 70 percent of households adopt cisterns by 2015. This results in 23 MCM/yr of new supply from rainwater harvesting in the West Bank.

UNEP (2001) has a detailed analysis of cistern use that estimates lower construction costs than those estimated by CH2M HILL. We have utilized the upper end of the UNEP range of $11–$15 per CM of developed capacity for the initial construction costs and have retained CH2M HILL's estimates of operation and maintenance costs, although we believe these represent the upper range of these costs. Because we estimate a lower yield from each cistern, the costs per CM of water are higher: The capital cost associated with this collection is estimated to be $0.98/CM of water, and the operation and maintenance costs are estimated to be $0.43/CM.

Wastewater Reuse. While none of the currently treated effluent is currently reused, CH2M HILL estimates that 25 percent of the 9.2 MCM currently treated can be reused in agriculture by 2005. It assumes that treatment capacity can increase up to 3 MCM/yr and that land availability and public acceptance will limit reuse to 50 percent of treated capacity in 2025, or 37.5 MCM/yr. The capital costs associated with treatment are estimated to be $1.09/CM, accounting for the purchase of 300 dunums (a dunum is about one-tenth of a hectare) at $7,000/dunum; the associated operation and maintenance costs are estimated to be $148 million, or $0.76/CM over ten years.

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[28] In other words, a rainwater capture system with 70 CM of capacity would cost about $1,200.

As a result of projections that reuse can become more acceptable to the public (Faruqui, Biswas, and Bino, 2001), our model is optimistic relative to CH2M HILL's assumptions discussed above. We included less conservative estimates of the amount of water that can be reused, based on CH2M HILL's upper-end estimates: We project that about 80 percent of the municipal and industrial demand (after UFW is accounted for) could be reused.

Because all wastewater will be treated regardless of whether it is reused, we attribute only the costs of reuse facilities (conveyance systems, storage reservoirs, and distribution systems) as costs of reuse. As a result, the capital costs are $0.14/CM and the operating and maintenance costs are $0.04/CM. If salinization of soils is deemed a significant problem, additional treatment costs will be incurred. Furthermore, if treatment facilities are not constructed reasonably close to agricultural areas, conveyance costs will increase.

Desalination. CH2M HILL estimates that a reverse osmosis plant desalinating 55 MCM of brackish water [10 grams per liter (g/l) salinity] annually (primarily from the Mountain Aquifers) will cost about $0.23/CM in capital costs and $0.59/CM in operation and maintenance costs over 30 years. A similar plant desalinating seawater (41 g/l salinity) is estimated to have the same capital costs and increased operating and maintenance costs—$0.97/CM. Other sources estimate that desalinating up to 1 billion CM of seawater by reverse osmosis would cost $0.55/CM to $0.65/CM (Abraham, Owens, and Brunsdale, 1999; UNESCO, 2001; Just, 1999) annually, including capital and operation.

Storm Water Capture. Our model uses CH2M HILL's baseline estimates of available storm water runoff: 15 MCM of storm water runoff from the wadis could be available in 2015 at $0.49/CM for capital costs and $0.02/CM in operation and maintenance costs. Only wadis with flows over 4 MCM/yr in the Jordan Valley and over 10 MCM/yr for those flowing into the Mediterranean were considered potential sources for storm water capture.

Water Network

Rectifying the lack of water and wastewater infrastructure, while necessary, will require significant investments.

Extending Centralized Supply. While connecting the entire population to the water network would be ideal, rural areas are difficult to serve; thus, CH2M HILL assumed a final connection status of 90 percent. The capital cost of attaining this 90 percent connection level and building a national water carrier is estimated at $109 million or $0.28/CM. Of this, $0.17/CM is the cost of components of the distribution network, such as pipes, fittings, valves, main transmissions, pumps, booster stations (a total of about $2.8 million), and a reservoir ($1.3 million). The remaining $0.11/CM is the cost of a national water conveyance system—about $13.2 million per year over 30 years. The operation and maintenance cost is estimated to be $324 million, of which

$0.02/CM is estimated to be upkeep on the distribution network and $0.34/CM to $0.57/CM (depending on quantity of water distributed) is estimated for operation of a national water conveyance system.

We have assumed that an expanded network will reach 90 percent of the population. The high operational costs of the national conveyance system are attributed to the energy required for pumping. We have additionally assumed that a national conveyance system (over and above the expanded network) is necessary only to distribute a major new supply, such as the output of a large desalination facility.

System Efficiency Improvements. CH2M HILL estimates that 45 to 60 percent of current supply is from UFW. It estimates that leaks—or physical losses—account for a 40 percent loss (the majority of the observed UFW). Based on UFW rates in the United States, CH2M HILL's model reduced this UFW to 15–20 percent of gross supply, adding an additional usable water quantity of 1.3 MCM/yr. The costs to reduce leaks are $0.33/CM for capital investments—amortized over ten years, including flow measurement and control devices. Of the $3,280,000 estimated for capital costs, 91 percent was estimated for physical improvements; water meter testing, acoustic survey, system layout preparation, hydraulic analysis of the system, and a pilot study each accounted for less than 2 percent of the capital cost, and field survey and site measurements accounted for roughly 3 percent. The operation and maintenance costs were figured as 5 percent of capital investment, and came to $0.13/CM.

We have used the costs as delineated by CH2M HILL. Actual costs, however, are likely to be substantially different. We have, however, varied the amount of UFW remaining to a minimum of 7.5 percent after targeting leak reduction, water meter errors, and detection of unmetered connections (Djerrari, 2003; Tonner, 2003). This projection is optimistic compared with CH2M HILL's analysis but can be achieved. Adequate investment to fix infrastructure problems will drastically reduce leaks, and legal connections for all will drastically reduce illegal use. Water meter errors can be targeted by introducing pressure management modules and changing to volumetric water meters (Nablus Municipality, 2003). Some estimates of the portion of UFW attributable to unmetered connections and illegal use are as high as 55 percent (Nablus Municipality, 2003).

Wastewater Treatment. CH2M HILL estimates that treated wastewater in 2001 totaled 9.2 MCM/yr, or roughly one-quarter of the 35.7 MCM of wastewater produced. By 2025, however, wastewater generation is projected to be about 215 MCM/yr, of which CH2M HILL projects only 75 MCM/yr will be treated. The projected total volume generated is based on the projected supply in 2025 minus the remaining UFW, or 85 percent of the supply. Based on its projection of wastewater generated and treated, CH2M HILL estimates the costs of treating 34.6 MCM/yr to be $33 million for capital costs, such as wastewater conveyance lines, pumping stations, and force mains (but excluding treatment plant costs). Costs to clean blocked lines, replace and repair old lines, and maintain pump stations are estimated at $148 million.

Other cost estimates in the literature are similar to those estimated by CH2M HILL. Secondary-level treatment is estimated to cost \$0.5/CM (Faruqui, 2002). The costs reported by CH2M HILL of providing centralized sewer systems, based on a Hebron regional plant, are similar in magnitude to those reported for a Nablus-West Wastewater Treatment Plant (Nablus Municipality, 2003). Because we estimate a more ambitious extension of the wastewater treatment systems to ensure no raw wastewater discharge, we include estimates of septic systems in addition to CH2M HILL's estimates of centralized treatment. To reach households where density is relatively low, on-site and cluster septic systems are likely to be more cost-effective than the centralized approach (North Carolina State University, 1998; EPA, 1997). Capital, operation, and maintenance costs amortized over 20 years can be as high as \$50/yr for such systems (North Carolina State University, 1998). Our model estimates that ensuring there is zero raw wastewater discharge for the remaining 15 percent will cost \$300 per household including both capital and annual operation and maintenance costs (Al-Sa'ed, 2000; UNEP, 2001). These costs account for the installation of small-diameter gravity sewers and a low-cost anaerobic treatment technology for groups of three homes.

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CHAPTER SEVEN

Health

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Summary

This chapter examines potential strategies for strengthening the Palestinian health system. We focus particularly on major institutions that would be essential for the success of the health system over the first decade of a future independent Palestinian state. In addition, we recommend several programs for preventive and curative care that are urgently needed and that could be implemented in the short term, with the goal of rapidly improving the health status and health care services of Palestinians.

The health system of a future Palestinian state starts with many strengths. These include a relatively healthy population; a high societal value placed on health; many highly qualified, experienced, and motivated health professionals, including clinicians, planners, administrators, technicians, researchers, and public health workers; national plans for health system development; and a strong base of governmental and nongovernmental institutions.

At the same time, there are important areas of concern. These include poor system-wide coordination and implementation of policies and programs across geographic areas and between the governmental and nongovernmental sectors of the health system; many underqualified health care providers; weak systems for licensing and continuing education; and considerable deficits in the operating budgets of the Palestinian Ministry of Health and the government health insurance system (the principal source of health insurance). There are also important and persistent health problems, including gastroenteric and parasitic diseases, hepatitis A, respiratory infections, and meningitis; high—and rising—rates of malnutrition; and rising rates of chronic disease. Also, access to health care has declined, along with social and economic conditions, since the start of the second intifada in 2000.

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